

The reality of virtual laboratories: a chemist's perspective

Rob Capon
School of Chemistry
The University of Melbourne
Rob_Capon@muwayf.unimelb.edu.au

Rob Capon maintains an active research profile in the field of marine natural products chemistry (PhD, UWA 1984). Currently he is Associate Professor in the School of Chemistry, University of Melbourne, and leads multidisciplinary studies into the chemistry of southern Australian marine organisms. He served as a DEET Senior Teaching Fellow (1991) and as the inaugural RACI Organic Division Occasional Lecturer (1994), touring Chemistry Departments across Australia demonstrating and lecturing on "Reaching for the 21st Century: Teaching with Interactive Multimedia". Rob is currently authoring a series of four compact discs, featuring multimedia software resources for teaching chemistry, scheduled for commercial release in 1996.

Some Background

A Chemists Perspective...

The observations outlined in this presentation are those of the author and focus on the introduction of new teaching technologies, in particular Computer Aided Learning (CAL), to undergraduate chemistry "laboratories" at The University of Melbourne.

The Venue...

Founded in 1856, the School of Chemistry at The University of Melbourne is one of the oldest in Australia. Some 35 academic staff are engaged in all areas of chemical research, and collectively instruct more than 2000 undergraduate and over 85 graduate students each year.

As with chemical education the World over, the School of Chemistry provides instruction in both the theory (Lectures & Tutorials) and practical (Laboratory) aspects of chemistry (organic, inorganic, physical). With more than 1600 undergraduate students studying first year chemistry each year alone, the logistics associated with this process are formidable. In 1993 as part of a major review of the undergraduate chemistry curriculum, the School of Chemistry undertook to implement both new strategies and new technologies into its first year teaching program.

New Strategies

In keeping with University directives the first year chemistry unit (Chemistry 101) was semesterized, and in order to more effectively support individual student abilities each semester unit was further partitioned into advanced (121 & 122), intermediate (141 & 142) and basic (161 & 162) streams. Individual selection into a given stream was determined at enrolment based on demonstrated academic ability in secondary level chemistry, physics and maths, while transfer between streams in second semester was a function of first semester performance. The precise formula for selection into streams continues to evolve, reflecting changes in both content and assessment at the secondary level. While the total lecture (39) and tutorial (13) load for each semester unit remained the same, the depth of coverage varied between streams in a predictable fashion. Perhaps one of the more controversial innovations to arise from this restructuring was a reduction in traditional Laboratory instruction (wet lab) from thirteen 3 hour to six 3 hour laboratory sessions, with the remaining seven 3 hour sessions being transferred to Workshops (dry labs). Over three years these Workshops have come to be exclusively CAL based. The rest of this paper will focus on the evolution and success of the Workshop concept.

Our First Workshop (Dry Lab)

The genesis of the Workshop concept, as currently implemented in the School of Chemistry, began to emerge in 1990/1991 as a handful of staff from the School of Chemistry became aware of and began to explore the application of computer technology in tertiary education. It is worth noting that in these formative times progress was entirely dependent on the efforts of a small number of enthusiasts, a situation which despite significant advances is regrettably all too often still the case today. In one foray into the application of computer technology a lecture theatre was equipped with computer projection capability and experiments performed to define and refine a methodology for “multimedia lecturing” to large undergraduate classes (over 250 students). Such “multimedia presentations” are now commonplace with most lecture and tutorial teaching spaces across the campus either upgraded or scheduled for upgrade to multimedia status.

Sponsorship

In late 1991 The University of Melbourne Interactive Multimedia Learning Unit (IMLU), with sponsorship from the Department of Employment, Education and Training (DEET), seconded as Senior Teaching Fellows three academics who through their actions had been identified as champions of multimedia technology. These individuals were supported (equipment, programmers & time-release) to more formally explore the application of interactive multimedia, and to provide tangible evidence for its future role in tertiary education. The author was fortunate to be awarded one of these Senior Teaching Fellowships, and used the opportunity to further refine methodology for lecturing with interactive multimedia, and to design and implement what was to become the first “dry lab” in the School of Chemistry, the Molecular Models Workshop.

The Challenge...

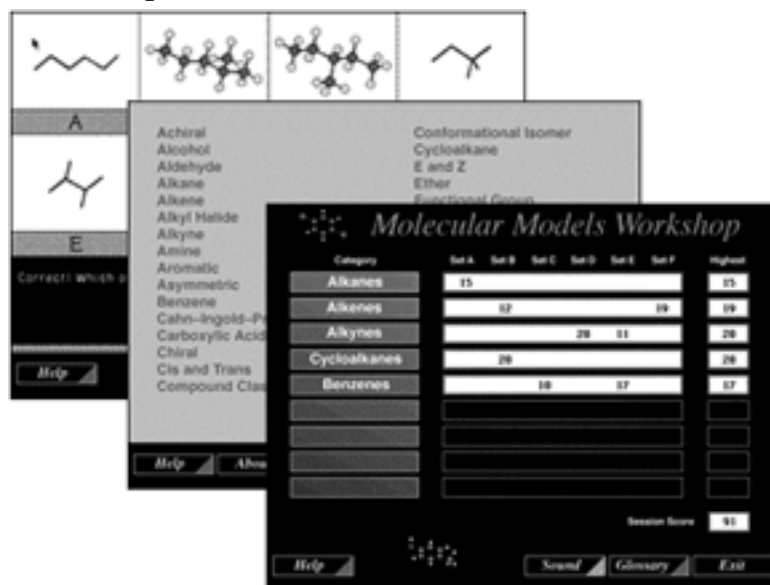
One of the more challenging concepts encountered by undergraduate chemistry students is that of molecular shape. To properly grasp the fundamental principles of molecular interactions — that is to predict the outcome of chemical reactions — it is necessary to fully appreciate the 3D shape of molecules, and to effectively integrate this knowledge into mechanistic theory. Traditional methods of instruction on blackboards *etc.* inevitably represent molecules in a 2D format, and require students to mentally recreate and comprehend the “correct” 3D structure. The speed with which individual students successfully acquire this ability to visualise the 3D structure of molecules is typically slow and varied. Traditional Molecular Model Kits are a valuable educational resource that offer students a tangible 3D “hands on” experience. Recognising the need to instruct students on the 3D nature of molecules, most Chemistry Departments run a Laboratory class where students are provided with a Molecular Model Kit and a printed set of instructions plus questions to work through. Over many years the School of Chemistry at The University of Melbourne ran just such an operation.

Molecular Models Laboratory Class...

During a given week, twice a day for three hours at a time, groups of up to 160 students would attend a Laboratory class. Prior to the class technical staff would check and lay out one Molecular Model Kit per student. Students would be divided into laboratory groups of 16 students per group with a graduate research student as a demonstrator. A member of academic staff would also be in attendance for the three hours of the Laboratory class. Over the allotted three hours students would assemble a series of molecular structures and attempt to answer questions about these structures (structural vs geometric vs stereo vs conformational isomers, *etc.*). During this period the students could ask questions of their demonstrator and the attending academic. At the conclusion of the class each student would hand up a report to the demonstrator. Over the next week each demonstrator would mark

(not correct) these reports which were handed back to their respective owner at the commencement of the next Laboratory class. The demonstrator would then manually enter a grade for each student (mark out of 10) onto a student record card. This grade would in time be “double typed” into the computerised student record for incorporation into the final assessment for the semester. Clearly this Laboratory class does not demand the costly resources and infrastructure of a chemistry laboratory. This Laboratory class appeared a prime candidate for re-development as a “dry lab” or Workshop.

Molecular Models Workshop



The Molecular Models Workshop (MMW) is a self-paced CAL package developed for use by undergraduate chemistry students. MMW presents students with a selection of problems focused around the shape of organic molecules — structural, geometric, conformational and stereoisomers, plus nomenclature *etc.* These problems are extensively supported by interactive molecular animations, on-line Help and Glossary functions, as well as real time assessment and feedback. Students are encouraged to explore MMW at their own pace, and to attempt additional questions to optimise their Session Score. This latter feature has been particularly successful in that individual students can immediately identify areas of weakness and respond accordingly. Student performance can be monitored and Class Assessment Lists generated automatically. MMW can be used by students for free range learning, or in a more formal tutorial/assessment setting. Class Attendance Lists can be preloaded into MMW for up to one month in advance to automate control over student access — an important consideration in our experience with more than 1600 students using only 40 computers over two weeks.

An early implementation of MMW saw the software loaded onto 40 computers in the School of Chemistry CAL Laboratory. Over two weeks, twice a day for 3 hours at a time, groups of 80 students would attend the CAL Laboratory to complete this Workshop. Although limited hardware resources required students to work in pairs, in due course this initial compromise was recognised as a bonus. Dialogue between pairs of students as they attempted to optimise their session score provided a powerful educational medium as each attempted to justify their version of the “correct” answer. Since student names, student ID numbers and allotted Workshop times were preloaded into the software, management of student access was fully automated. Likewise, on-line assessment ensured that students were immediately alerted to incorrect answers and encouraged to explore more questions on that topic. Not only did students know their final assessment at the end of the Workshop, but this score was automatically logged and used to generate a consolidated assessment list

for all students. At no time were student names, numbers or grades re-typed, rather they were uploaded direct from the MMW logfile output into the University assessment archive. Once the MMW software was loaded onto the CAL Laboratory computers, instructional support for each group of 80 students was possible by a single academic, and the entire assessment upload of more than 1600 students achieved in about 15 mins by one person.

The design and development of MMW required consideration of many issues, both academic and technical.

Academic Content & Design

MMW was designed to replace an existing laboratory class. As such both the content & design needed to acknowledge that link. Sparse access to demonstrator support during the traditional laboratory could be compensated for by immediate on-line assessment (Am I correct or incorrect, and if so how do I proceed?) and Glossary (What does this term mean?). In the event that students first attempt at a set of questions was poor (low score) they should be given the opportunity to immediately try another set of related questions. The students are encouraged to take responsibility for assessing areas of strengths and weakness, and respond accordingly. The incentive for the students to focus on an area of weakness is that by trying another set of questions they will learn more about the concepts covered in these questions, and in the process improve their session score. Descriptions in the Glossary were kept deliberately brief — sufficient to remind a prepared student but insufficient to fully explain the meaning of a difficult concept. At all times students were encouraged to make reference to a chemistry textbook. The MMW was not designed as an alternative to, but rather complimentary to existing textbooks. The design was also required to provide automated support for student access and assessment.

Hardware (Production vs Delivery)

QuickTime animation technology which is the ‘nucleus’ of MMW was initially released on Macintosh platform, and as the School of Chemistry is overwhelmingly a Macintosh environment, this clearly identified the development and delivery hardware.

Authoring Software (Production vs Delivery)

Available programmer support combined with the need to manage emerging QuickTime technology in a Macintosh environment readily identified HyperCard as the Authoring software of choice, both for production and delivery.

On-line Help and On-line Glossary

With conceivably more than 1600 users/year it was essential that all user notes *etc.* be incorporated into MMW. The on-line Help feature is accessible at all times and clearly explains both the academic and technical design, requirements and objectives in using MMW.

Timetabling limitations consistently resulted in students using MMW *before* attending lectures on most of the topics assessed in the Workshop. An on-line Glossary is accessible to students at all times during a session and provides brief descriptions that may be sufficient in themselves or may serve as points of entry into a chemistry textbook. The Glossary is HyperText linked to facilitate browsing.

Distribution

Although MMW was initially developed to demonstrate the effective application of this technology, it was recognised early in the development process that MMW would have application outside of the University of Melbourne. Indeed, many other Universities across Australian and overseas have expressed interest in obtaining MMW. Realistically, commercial distribution of MMW is only viable if a dual Macintosh/PC version can be

created. Having refined MMW in a Mac environment we are currently contracting its porting to PC, as a prelude to commercial distribution late in 1996.

Evaluating MMW

Having created a working version of MMW more than 2500 students used the package over two years. These students were invited to answer an “electronic” questionnaire on all aspects of the software. Likewise, the logfiles for each student usage contained additional information that was used to measure the effectiveness of individual questions. Impromptu interviews with students during Workshops also provided a valuable level of feedback. The feedback from both questionnaires, logfile analyses and interviews was used to refine MMW.

Our experience with MMW was very successful. Students benefited from both the self-paced nature of the product, the built in assessment and feedback, and the visual clarity of interactive molecular animations. Tedious administrative issues (marking attendance roles and reports, entering student assessment *etc.*) were handled by computers and valuable academic and demonstrator support redeployed to student instruction. Although the first CAL Workshop, MMW was not the last. Many effective CAL packages have since been adopted as integral components to the undergraduate chemistry curriculum.

School of Chemistry CAL Laboratory

Establishment

Trials of CAL were undertaken in 1992, making use of the University of Melbourne, Information Technology computer laboratories. Although not traditionally a teaching venue, these laboratories were opened up to the School of Chemistry to provide the large number of computers needed. Remote from the chemistry building and subject to numerous practical constraints, access to these laboratories still provided the means to successfully implement CAL and unambiguously demonstrate its potential in tertiary education. Following on from this success the School of Chemistry undertook to construct its own CAL Laboratory by commencement of the 1993 academic year.

Discussion so far has focused on Workshops as ‘dry’ labs, that is computer based versions of traditional laboratory classes. While the viability of such operations has been well demonstrated, CAL Laboratories offer far more. The School of Chemistry has had considerable success with an in-house development, Tutorial Tools, which has facilitated the production of numerous self-paced interactive tutorials. Furthermore, copies of electronic lecture material, “worked” answers to tutorials and past exam papers, all feature in the repertoire of resources made available to students through the CAL Laboratory.

Management

The Chemistry CAL Laboratory is supported by a full time programmer, charged with both ensuring the smooth and efficient operation of the laboratory as a teaching environment, and in monitoring and supporting future development and the implementation of emerging technologies.

Access

The CAL Laboratory is scheduled for Workshops 10am-1pm and 2pm-5pm each day Mon to Fri. Times 8am -10am and 5pm -7pm are variously available for scheduled classes and/or free access for private study. In 1996 at least one Workshop is scheduled 6pm-9pm. The physical location of the CAL Laboratory together with security and safety considerations make it difficult for late night and/or weekend access to undergraduates.

“Commercial” Workshops (dry labs)

Another laboratory exercise which derives no obvious benefit from being in a chemistry laboratory is the spectroscopic identification of an organic unknown. Permutations of this experiment occur in all years of undergraduate instruction and invariably require the identification of an unknown substance given a selection of spectroscopic data. While first year students traditionally solve one such unknown, second year students solve two and third year students three. In all cases the students write and submit a report which is marked/assessed and after some delay (up to 1-2 weeks in third year) returned to the student. In first year the large number of students involved frequently ensure that this unknown is marked but not corrected — providing little educational feedback to the student. Ideally students should have an immediate answer to their effort at assigning a structure and, if incorrect, receive hints at why they were wrong and be prompted to try again. Likewise, whether students get the correct or incorrect answers all would benefit from the opportunity to attempt numerous examples. Enthusiastic students should be encouraged and supported in this regard. For practical reasons it is impossible to offer these ‘ideal’ opportunities in a traditional laboratory class format — they are however attainable through the use of CAL.

Several commercially successful CAL software packages are available to support a Spectroscopic Unknowns Workshop. Two that we have made use of in first and second year are Introduction to Spectroscopy and Proton NMR Simulator.

Future Directions

Hardware

At present Universities making use of CAL are obliged to provide access to and maintain expensive CAL laboratories. Whether this will be necessary in the future is open to speculation. As the cost of powerful laptop and desktop computers/modems *etc.* falls, students will increasingly invest in this equipment. To provide access to CAL content it may be sufficient to provide network access both on or off campus. In the final analysis, quality software with on-line support/assessment may be made available to students on demand, with occasional electronic communication to a rostered “human tutor”.

Software

As mentioned above, should CAL software be accessed from off campus then the very real opportunity exists to supply these software resources as a worldwide service. Smaller institutions lacking infrastructure for software development may choose to purchase site licenses and/or enter into collaborative associations with software suppliers. These suppliers need not necessarily be other Universities but may be specialist software development teams working in concert with skilled educators — in the same country or overseas. Indeed, these technological developments may provide the most effective means yet to forge a practical association between individual discipline and educational experts.

Networking

Arguably the short to medium term future for CAL delivery is the World Wide Web. This environment offers cross platform support, allows for full networking and all the benefits that flow from that (managing corrections, upgrades, access, *etc.*). Whether this networking is campus restricted or supports off campus access is a local issue. It is however inevitable that WWW sites will emerge that offer excellent, high quality, technologically advanced, educational resource material.

Individual academics responsible for course development may feel justified in ignoring these exciting technologies, but it is doubtful that students in search of quality education will be so inclined.